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The Impact of Robotics-Enhanced Approach on Students' Satisfaction in Open Learning Environment*

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The purpose of the paper is to investigate whether a technology-intensive open learning that promotes constructivist approach has a significant effect on the student satisfaction, cognitive load, and psychomotor difficulty of the robotics course. A technology-intensive course must address the following outcomes: demonstrate a sound understanding of several technology concepts, systems, and operations, use a variety of technologies to access, evaluate, collect, and manage data, information, and datasets, understand the impact of technology on themselves and their culture, environment, and society, and practice legal and ethical behavior in the context of technology. For this purpose, four cohorts of middle school students were recruited (n = 267). Two consecutive robotics-enhanced Summer School 2012 and Summer School 2013 were organized with experiential learning cycle followed by two consecutive performance of open learning of robotics at Technology Days, performed in 2014 and in 2015, using inquiry-based learning method in real-classroom settings. Open learning of robotics refers to minimal constraints on access, pace and method of study where direct manipulation environments are used very often to increase student success. Technology Days as compulsory part of curriculum are aimed to develop positive attitude towards technology and to advance technological literacy using mostly inductive strategies and approaches to learning. Multivariate analysis of covariance and regression analysis were performed to determine the contribution of predictor variables to students' cognitive, emotional and behavioural course outcomes as the important outcomes that influence a success of instructional intervention and the decision to continue or drop-out of a course. The results showed that composite variable of learning environment was a good predictor of student satisfaction and psychomotor easiness; learning material improves processing fluency; self-efficacy predicts satisfaction while self-regulated learning enables psychomotor easiness. Surprisingly, interactions among students and content did not significantly contribute to the predication of student satisfaction, nor to perceived course easiness. Additionally, experiential learning facilitates cognitive processing fluency, considering joint effects with variable of sex seemed to have influence on student satisfaction. The results of the study suggest to influence students' motivation and goals by adapting instruction accordingly.

Keywords: robotics; constructivism; student attitude; satisfaction; cognitive load; psychomotor difficulty

1. Introduction

During the last decade robotics has attracted the high interest of technology and engineering teachers and researchers as a valuable tool to develop not only for design and engineering supporting learning environment, but also cognitive, social, and psychomotor skills for students on entire vertical of schooling and study [1]. An impact of social robotics is even more crucial for children and teenagers, where robots can be used for their development, intellectual growth, and creativity [2, 3]. Even of positive experience of robotics in education, a middle school robotics subject matter is seldom to be compulsory subject, more often attributes as optional or elective subject [4, 5]. There is emerged need for the integration of robotics subject matter into the lives of young people [2]. The content of robotics subject matter is already framed in formal curriculum, but performance of robotics-enhance learning is rather organized in open learning environments [4–6]. Open learning of robotics is organized in summer schools, bridging courses, and in other out-of-school activities where a convinced sample of students with more positive attitude toward robotics is recruited. Summer schools and camps very often using an experiential learning (EL), which broadly supports students constructing their own learning about their collective experience [7], while inquiry-based learning (IBL) supports students constructing their own learning about the phenomenon using science process skills to gather evidence about the phenomenon [8, 9].

The most important course outcomes of open learning may refer to cognitive, emotional variables [10], and behavioural or psychomotor variables [11, 12]. On the side of cognitive variables, learning achievements and cognitive load are considered most important. Cognitive load of instructional conditions is not to be considered as a by-product of learning [13] but should rather be considered as the "major factor determining the success of an instructional intervention" [14, p. 64]. On the side of emotional variables, satisfaction with a course is

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an important outcome, while at behavioural variables, load that influences the decision to continue or drop-out of a course [10]. Behavioural variable of psychomotor difficulty or easiness of the course should be considered to asses a delay in the acquisition, coordination, and execution of psychomotor skills that are not learned through an explicit education [11].

In spite of several studies to explore robotics-enhanced learning environment, an effective and a clear visualization of predictors affecting course outcomes is still lacking.

In last four years, two Europe Union funded projects were set to promote among other also robotics in education, namely INFIRO project (lasted 2011–2013) where EL of robotics was used as a learning method [6], and CHAIN REACTION project (lasts 2013–2016), where IBL of robotics was used to promote science, technology and engineering studies [5, 15]. These two cases were used as content and context framework for our study.

Therefore, the objective of this paper is to investigate what factors in robotics-enhanced open learning in real-classroom settings predict significantly students' satisfaction, cognitive load and psychomotor difficulty of the course.

We contribute to the literature by providing evidence of an association between individual EL and IBL acceptance factors, and the performance in the context of the middle school robotics-enhanced open learning environment. Especially, scientists, educators, and course designers in technology and engineering education can benefit from this.

2. Theoretical background

Robotics subject matter are slowly beginning a process of a seamless integration in education [2–4] where students themselves are well aware of the necessity of learning about robotics because of their likely ubiquitous presence in future society [4]. Competiveness on the market, technological and social perspectives urge schools to prepare pupils for robotics [3, 4]. To date, a little research has been conducted into learning and teaching robotics in a middle school setting, noticeable work has focused on students remembering, understanding and using of robotics subject matter [1, 2, 5] stressing the importance of interaction with concrete materials. We therefore suppose that robotics may best be learned by having students work in a context with realistic robotic problems including designing, constructing, programming, testing and optimizing, and not just by talking or reading. In engineering education, design thinking has been suggested to improve student retention, student satisfaction, diversity and students' learning [16]. The method of design thinking is described as a sequence of phases linking discovery through to ideation and then prototyping or model making [17]. It is a 'making' and 'doing' approach based on a set of heuristics, for example show don't tell [17]. Moreover, we suppose that student active learning should be scaffold with teachers, and peers or groups by asking questions, providing feedback, pointing out inconsistencies, and elaborating on experiences and information. This strategy of constructivism may be conducted through EL and/or IBL [17], where the largest amount of student engagement in learning is achieved, along with higher order thinking skills to extend and to advance of learning achievements and creativity [3] on other cases or problems. Recent researches reveal that important technological concepts, such as system thinking, critical thinking, design, and the form-function principle, have to be learned in a variety of relevant contexts [2, 4, 17]. Such context of robotics may refer to advances in course achievements, especially perceived cognitive load [18], students satisfaction [6, 9], and perceived psychomotor difficulty of the course [12, 20].

2.1 Constructivist approach

The constructivist approach is one of many instructional approaches that use meaningful tasks such as cases, projects, and research to situate learning. Students work in collaborative and cooperative groups to identify what they need to learn to solve a problem, gain research skills, and enhance trade-off capacity [15, 17]. Both, the IBL and EL are inductive learning strategies that enable learners to construct and process knowledge, develop reasoning skills, and to increase interest, learning motivation, and creativity in technology-intensive learning environments [3, 8]. Alfieri et al. argued that "allowing students to interact with materials, models, manipulate variables, explore phenomena, and attempt to apply principles affords them with opportunities to notice patterns, discover their underlying causalities, and learn in ways that are seemingly more robust" [21, p. 3]. The effectiveness of active learning approaches in open learning settings is still a matter of debate at all levels of education [1, 2, 19], thus a need has emerged for a design of contemporary and sustainable active learning where a large amount of creativity is enabled [3].

2.1.1 Experiential learning

The EL model portrays two dialectically related modes of grasping experience—Concrete Experience and Abstract Conceptualization—and two dialectically related modes of transforming experience—Reflective Observation and Active Experimentation, Table 1. EL defines learning as "the

Table 1. Kolb's experiential learning cycle stages at robotics-enhanced learning [23]

Kolb's stages	Description
Concrete experience	Learning starts with concrete experiences, in which the learner is engaged. The knowledge cannot be "copy-pasted" into a learner's head, but learning is most efficient if content is experienced by each individual.
Reflective observation	This stage is all about observation. The phase is important and can have motivational impact if observed facts are in conflict with accommodated knowledge. If this "surprising factor" is presented, numerous questions are generated. The learner is automatically self-guided to the next phase of conceptualization.
Abstract conceptualization	In this stage a cognitive process is triggered with an interpretation of the event and findings of meaningful explanations for it. At this point a new learner's knowledge is constructed and therefore this stage is the most important part of the learning cycle.
Active experimentation	The last stage is intended to be a contextualization of new learned knowledge in order to be beneficial in the cognitive level of synthesis. In this active experimentation, a process of planning and making predictions is performed in order to subject a theoretical conception to the test.

process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" [22, p. 41].

The EL is an educational orientation which aims at integrating theoretical and practical elements of learning for a whole person approach, emphasising the significance of experience for learning. Learning is best conceived as a process, based on collective experiences, not in terms of outcomes [7]. Learning is the process of creating knowledge and gaining skills. EL proposes a constructivist theory of learning whereby social knowledge is created and recreated in the personal knowledge of the learner [7]. EL can be repeated several times in order to completely achieve certain learning objectives. EL is a process of constructing knowledge that involves a creative tension among the four learning modes that is responsive to contextual demands [7].

2.1.2 Inquiry-based learning

IBL is a learner-centered approach where critical thinking, problem solving, and communication abilities are more important than simply having knowledge about the content of learning [9, 24]. IBL may take several forms, including analysis, problem solving, discovery, and creative thinking activities [21, 25]. IBL was developed in response to the perceived failure of more traditional forms of instruction, where students were required simply to memorize fact-laden instructional materials [25]. IBL is a form of inductive pedagogy, where progress is assessed by how well students develop experimental, analytical, creative, and reflective skills rather than by how many competences they possess [26]. Effective IBL implementation is demonstrated through students' performance as formulation of good questions, identification and collection of physical evidence, systematic presentations and elaborations, resolving misconceptions, and management of concept transference [27].

Several types of IBL are discussed in the literature, and they are primarily based on three important qualifiers about the nature of inquiry: the level of scaffolding (amount of learner self-direction), the emphasis of learning, and its scale (within-class, within-course, whole-course, and whole-degree) [28]. All IBL models emphasize the following levels of inquiry that differ from one another in significant ways [8, 27]: (1) confirmation inquiry, (2) structured inquiry, (3) guided inquiry, (4) open inquiry, and (5) blended inquiry. Well-designed IBL environments can enhance students' learning experiences [24]. IBL tends to improve students' self-regulated learning abilities, but optimal guidance during instruction has to be provided for effective IBL [24, 29, 30]. Improvement of transferable skills such as teamwork, independent learning, and problem solving skills in a real-world situation can hopefully improve critical thinking, problem solving, and reduce time pressure in other technology-intensive courses [30]. A technology-intensive course engages students in the use of different technologies (production, information, or measurement), and is defined by the following outcomes where students should understand several technology qualifiers and impacts in order to be able to use, judge, assess, and manage different technologies [24].

IBL has been recommended as a leading instructional strategy for science, but has several limitations in technology-intensive education [24, 30, 31, 32]. These limitations are in the instructional materials, learning-process planning used, and the assessment, motivation, and the measurement of metacognitive reflection.

2.2 Open learning course outcomes

When designing an IBL and an EL course, teachers and course designers are faced with several qualifiers of real-world classroom scaffolding learning in order to affect students' experience, knowledge construction and processing, and acquiring skills. Decisions related to the didactic design of a course may refer to one of six fields of open learning [6, 10, 12, 27]: (1) Prior-knowledge and capacity, (2) context, (3) content and learning material, (4) learning process,(5) strategy of reaction and behaviour, and (6) Course outcomes.

The course outcomes may refer to cognitive, emotional, and behavioural or psychomotor variables. Learning achievements are considered most important in cognitive variables, which can be described as different facets of competences such as theoretical and methodical knowledge as well as the skills required for problem solving, personal/ social competences (e.g., in self-regulated or collaborative learning), and/or technological competence [12,32]. Cognitive load is also very important variable which influence a success of instruction intervention [13, 18]. Cognitive load should be seen as [13, 33, 34]: (1) Extraneous load which can be attributed to poor layout, equipment or to a surplus of information on learning objects. Extraneous cognitive load is cognitive load that is evoked by the instructional material and that does not directly contribute to learning (schema construction). This type of load can be altered by instructional interventions; (2) Intrinsic load may refer on complexity of learning material, and it cannot be changed by instructional treatments [34]. Intrinsic load is an interesting concept that helps explain why some types of material are more difficult than others and how this may influence the load on memory [34]; and (3) Germane load, which is associated with interactivity. The germane load is imposed by processes of interpreting, exemplifying, classifying, inferring, differentiating, and organizing. Instructional designs should, of course, try to stimulate and guide students to engage in schema construction and automation and in this way increase germane cognitive load. De Jong [34] argued that students in the self-generated organizer condition obviously had experienced more extraneous load, but it also might have been the case that these students had to perform germane processes that were too demanding. Self-regulated learning may causes overall cognitive load to exceed learner working memory limitations, and in that case, the germane load could effectively become a form of extraneous load and inhibit learning [35].

In emotional variables, student satisfaction with a course is an important outcome that influences the student's decision to continue or drop out of a course [6, 10, 27]. Previous studies have determined some factors that influence student satisfaction in real-classroom learning environments [6, 12, 36]. Avsec and Kocijancic already confirmed factors of learning environment, learning material, and self-efficacy [12], and it seemed that some elements of self-regulated learning can predict student satisfaction, also confirmed by [17, 36]. Interactions (learner-content, learner-learner, learner-teacher) may be decisive factor to student satisfaction, but student disengagement should be considered carefully [18, 37] especially at learner-content interactions.

Psychomotor variable outcomes are based on the perceived psychomotor difficulty or easiness of the course [11]. Self-regulated learning can be a good predictor of psychomotor difficulty [11,12, 38]. Learning environment should be considered carefully, some implications of user friendly environment were found that increase load [6, 34]. Self-efficacy can contribute to perceived easiness of the course [12, 14, 33]. Interactions, especially learner-content may be treated carefully, because students disengagement and bad work habits can contribute to perceived difficulty of the course [13, 34].

In the next sections, the methodology, which includes the course format, the sample, instrumentation, and procedure and data analysis, of this study is described. Then, the results are reported and the study is critically discussed. In the concluding section, answers to the research question are formulated.

3. Methodology

Robotic direct manipulation learning environment is used as a learning context. The course format, samples, instrumentation validation and specification, procedure and data analysis of our study are described in the following sections.

3.1 Course format

Educational robotics is introduced as a powerful, flexible teaching/learning tool stimulating learners to control the behaviour of tangible models using specific programming languages (graphical or textual) and involving them actively in authentic problem-solving activities [1]. Therefore, teaching of robotics claims from the teacher knowledge and skills to include computing, electronics and mechanics subject matter into a meaningful subject. The course learning objectives were taken from the Slovenian national curriculum for the optional subject "Robotics in technology engineering". These learning objectives are well-defined and linked to student activities. They can be classified into three difficulty levels: minimal, basic and advanced [5]. We chose objectives from each level and arranged them into associated areas of robotics. The selected objectives are presented in Table 2.

This knowledge provides good fundamentals from which learners can derive their creative skills for their own projects in the future. Open learning

Table 2. Classification of tested learning objectives

	Learning objectives level		
Knowledge domain	**Minimal**	**Basic**	**Advanced**
Electrical Engineering	Know the effects of electrical current on the direction of the rotation of the motor shaft.	Explain the properties of light and other sensors in the role of on/off action.	Are able to read and draw electrical schematics and assemble the correct circuits from those schematics.
Computer Science	Are able to use the S-R-A loop properly.	They know the differences between digital and analog input.	They know the purpose of the ADC (Analog to Digital Converter).
Mechanical Engineering	Understand the role of the gearbox to reduce speed of shaft rotation.	Know and understand the operation of various mechanical components (worm-gear)	Constructing the various robotic models that are able to move in three directions.

content was based on constructivist approach which provides students the deeper, more solid and transferable knowledge [4, 31]. Therefore, the learning was scaffold as EL at Summer Schools and IBL at Technology days. According to the didactic concepts of EL and IBL, we chose a mobile car project shown in Fig. 1 with five position markers that may have a significant impact on the learning content [15]: (1) Fischertechnik DC motor, (2) The gearbox, (3) A push-button switch with three contact terminals and electrical scheme, (4) Construction bricks with integrated all-purpose elements, and (5) Easy incorporation of third-party elements by using the reversible assembly as a screw linkage. The entire learning process was composed of several tasks outlined in [5].

Students construct their knowledge based on their experiences and guided inquiry. Some students may provide correct responses regarding how things work very quickly, while others must repeat learning cycle several times. It is very important that they are able to draw on the theory learned and make successful predictions about the relevant outcomes for the various combinations. Teachers should respond, particularly to incorrect responses, since those could lead to entrenched misconceptions of the theory. However, students should not simply be told to memorize theoretical facts. Rather, they should be led through the different scenarios and encouraged to recognize incorrect conclusions and adopt the correct ones. Students activities and learning environments of our study are entirely described in [6] for Summer School and in [5] for Technology Days.

An IBL 'Technology Days' course is offered within the compulsory program in middle school around the Slovenia. An IBL was conducted in real-world classrooms and laboratories, with two tech-

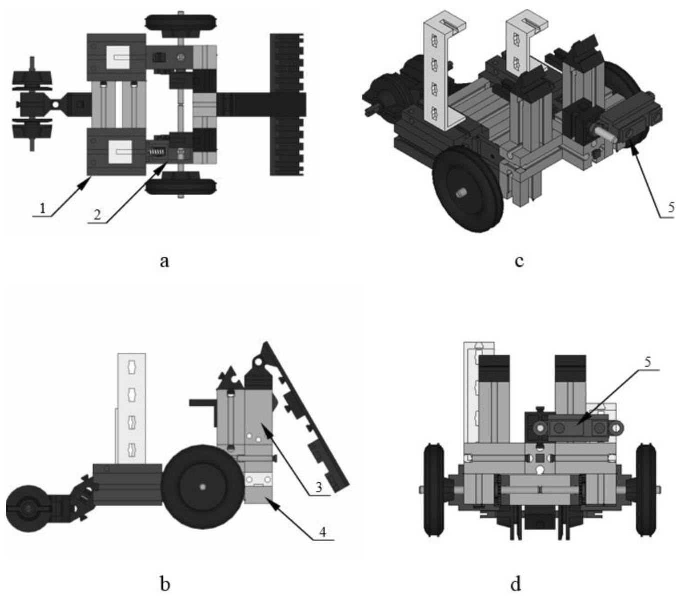

Fig. 1. Mobile robot model (a, top view with mounted bumper; b, side view with mounted bumper; c, isometric view with IR distance sensor; d, front isometric view (with IR distance sensor) and important parts marked from 1 to 5 where is: 1—Fischertechnik DC motor, 2—Gear box, 3—Push-button switch with three contact terminals, 4—Construction bricks with integrated all purpose elements, and 5—Reversible assembly as a screw linkage [5].

Table 3. Students' distribution and activity phases in EL and IBL group

Middle school	EL group Day 1–3 EL, Day 4–5 workshop +Survey	IBL group Day 1 IBL	 Day 2 IBL	 Day 3 IBL+ Survey	Number of students
INFIRO Summer school 1	June 2012				44
INFIRO Summer school 2	June 2013				61
K.M. Ljubljana		Nov 2013	Dec. 2013	Jan. 2014	19
Mokronog		Dec.2013	Jan. 2014	Feb. 2014	17
Vrhnika		Dec. 2013	Jan. 2014	Mar. 2014	17
Cerklje na Gorenjskem		Dec. 2013	Jan. 2014	Feb. 2014	20
Radovljica		Jan. 2014	Feb.2014	Mar. 2014	18
Sežana		Oct. 2014	Nov. 2014	Dec. 2014	15
Šentjernej		Oct. 2014	Nov. 2014	Jan. 2015	12
Črnuče		Oct. 2014	Nov. 2014	Dec. 2014	14
Kranj		Oct. 2014	Nov. 2014	Dec. 2014	14
Dol pri Ljubljani		Oct. 2014	Nov. 2014	Feb. 2015	16
Total					267

nology teachers as instructors. IBL activities were three days long (6 periods a day) with the break period of 3–6 weeks, depends on the school plan. Learning-based work was ignited and controlled by role models.

The entire activity consists of related components; where the use of various forms of learning to effectively achieve the objectives. Students could work in a number of groupings during this activity. All the approaches emphasize that learners are actively constructing knowledge in collaborative groups. The roles of the student and teacher are transformed. The teacher is no longer considered the main repository of knowledge; he is the facilitator of collaborative learning. In IBL, students become responsible for their own learning, which necessitates reflective, critical thinking about what is being learned. In IBL, students are asked to put their knowledge to use and to be reflective and self-directed learners [15].

Students at robotics-enhanced learning were actively doing—solving the multi-parametric problem (key parameters spin-off), designing different robotic systems, creating own experiment, measuring parameters variations and its impacts; advisor is encouraging and keeping focus on the doing. Students were evaluating, employing meta-cognition to understand not only what was learned (technological knowledge) but how it was learned (transferable skills) and how (why) this fits into future learning needs (critical thinking and decision-making); advisor models self-analysis, interpretation, and explanation. The social learning using design thinking was enabled which enhances creativity [3], reduces germane load [34], and improves decision making ability of students [17].

3.2 Research design and samples

Action research is used as a type of evaluation that seeks to determine whether a robotic-enhanced constructivist approach in open learning environment had the intended causal effect on program participants. There are three key components of action research design: (1) course planning, (2) learning process, and (3) changes in behaviour. Two groups received the EL treatment, while the other two received an IBL in open learning course of technology education consonant with the research recommendations from the cognitive science perspective on learning and instruction. Entire learning approach's samples and activity phases are shown in Table 3.

Variables considered in the study were: (1) Independent (IV): Students (e.g., experiences, type of the group, sex) in groups; and (2) Dependent (DV): Course outcomes measured with satisfaction and perceived course difficulty measure (cognitive load and psychomotor difficulty of the course).

The sample of this study was drawn from four cohorts of middle school students (n = 267, 189 males, 78 females). An EL method was introduced first at Summer School in June 2012 were 44 students (n_m = 36, n_f = 8) were enrolled, and the second EL at Summer School in June 2013 with 61 students (n_m = 52, n_f = 9). The venue of both summer schools was City of Rabac in Croatia. Summer School duration was of 5 days, with 25 learning periods in total. Experiential learning groups consist of 105 students (88 males, 17 females). Inquiry based learning was first conducted in study year 2013/14, from November 2013 to March 2014, depends on school program and curriculum. Five middle schools around Slovenia (Table 3) were engaged in study, with 91 students (n_m = 59, n_f = 32). The second year of IBL was 2014/15 at five another middle schools where were of 71 students (n_m = 42, n_f = 29) were enrolled. Middle schools, which have been recruited in this study, were selected by IBL role models (scientist from university, applied science researchers).

Entire IBL course was 3 days long (18 periods) and the national conference of IBL (5 periods) where best groups two (three) groups from each school presented and defended their findings. Students were aged 14 ± 1 years.

3.3 Instrument

Student experiences, satisfaction, and perceived course difficulty were considered important for the long-term success of robotics-enhanced constructivism in open learning courses. The findings from literature review revealed subscales for technology-intensive open learning in real-classroom settings. For this purpose, a researcher-developed questionnaire addressing the specifics of the course offerings was administered to the students. The survey items were validated by an expert panel. Two stages were involved in the instrument development process: (1) To ensure the content validity of the instrument, a content validity survey was conducted. The expert content validators were university professors (six) and middle school technology teacher experts (three). Reviewers were asked to rate each item out of forty items and determine whether the item was adequate for these specific domains on a basis of three choices: essential, useful but not essential, and neither essential nor useful. Content validity ratio (CVR) was calculated based on the ratings from these nine experts. The threshold of CVR value to maintain an item for a case of nine reviewers is 0.65 [39]. Items measuring similar concepts or with a CVR value lower than 0.65 were either removed or combined with other items. (3) The slightly revised items and combined items were sent back to the reviewers for a second-round rating to ensure they were adequate and necessary. An expert panel provided evidence of survey content validity. After item elimination and revision, there were four items in each subscale, thirty-two in totals. The Cronbach's coefficient alpha values, calculated based on the sample of this study, indicated the developed instrument is reliable (Table 4).

The survey consisted of eight groups of questions with four items. Instrument development was required for the factors affecting the EL and IBL process. For the assessment, a 7-point phrase completion scale was used. The scale intervals form a continuous type from 1-minimum to 7-maximum. The scale does not present the mean, but ensures the comparability of continuous responses and produces better assumptions of parametric statistics while avoiding bias [40].

Table 4. Reliability information for subscales with four items in each

Scales	Cronbach' alpha
Learning environment (LE)	0.91
Learning material (LM)	0.80
Self-efficacy (SE)	0.71
Self-regulated learning (SRL)	0.83
Interactions (I)	0.78
Cognitive load (CL)	0.77
Psychomotor difficulty (PD)	0.78
Overall satisfaction (S)	0.81

3.4 Procedure and data analysis

Students participated in the study during real-world classroom sessions throughout a school day. Since the summer school of robotics was one week long and it was divided into three-day long learning activities (15 periods) and two-day long workshop (10 periods) of creating their own robots followed by communicating results to the participants. The EL was organized in small groups of 4–6 students. The Technology days group students participated in IBL in small groups of 3–4 students (4–6 groups at the class level). Administration of the survey was performed when learning activities were ended, in one-shot study, depending on the school curriculum and activity plan. High response rate was obtained by direct presence of teachers, instructors, and test administration. With the permission of and assistance from the parents and instructors who agreed to have their students participate in the study, a paper and pencil survey were distributed accordingly. All (n = 267) of the enrolled students completed the test.

Data analysis was conducted using SPSS 22. Descriptive analyses were conducted to present the student basic information, the mean score of predictor variables, and of student satisfaction, cognitive load and psychomotor difficulty as DVs. Correlation analysis was performed to understand the relationship between the five predictor variables and three DVs. A multivariate analysis of covariance (MANCOVA) was used to find between-subjects contrasts considering three depended variables. Multiple regression analyses were performed to investigate whether predictor variables significantly predict student satisfaction, cognitive processing fluency and psychomotor easiness. The measure of the effect size is η^2 (eta squared). Durbin-Watson test is applied for checking serial dependence.

4. Results

Our findings are reported as descriptive analyses of survey data, correlation analyses, and (Co)Variance and regression analyses.

4.1 Descriptive analyses of survey variables

Table 5 depicts the average scores on the subscales. Most of the students had a high level at any subscale

Table 5. Descriptives about survey *subscales* and items with a range 1–7 and a midpoint of 4 (n = 267)

Items	M	SD
Experiences concerning learning environment (LE)	5.67	1.30
LE1—Classrooms and laboratories are well equipped and organized	5.63	1.40
LE2– Learning environment is user friendly	5.79	1.49
LE3—Each student has enough room for research and creative work	5.71	1.51
LE4—Refreshment and snacks are available, easy on access	5.54	1.51
Experiences concerning learning material (LM)	5.80	1.05
LM1—Learning material is up to date and actual	5.78	1.13
LM2—Material gives enough information for inquiry	6.06	1.43
LM3—Learning objectives are clear and well designed	5.70	1.50
LM4—Learning material was of multiple forms and types	5.64	1.29
Experiences concerning self-efficacy in learning (SE)	5.57	1.15
SE1—Active learning and practical work are enabled	5.62	1.41
SE2—Assistance, self-directed and collaborative work are enabled	5.71	1.52
SE3—I was effective, no need for extra help or teacher guidance	5.12	1.89
SE4—Explanations and instructions were clear and comprehensible	5.84	1.43
Experiences concerning self-regulated learning (SRL)	5.83	1.26
SRL1—Learning was effective and success controlled via tests	5.94	1.49
SRL2—Learning was creative, own ideas were well considered	5.79	1.65
SRL3—Own learning and training pace was enabled	5.72	1.53
SRL4–I can strongly recommend this learning to fellow students	5.87	1.51
Experiences concerning interactions (INT)	5.67	1.12
INT1—Content is attractive, contemporary, interactive, suits for males and females	5.58	1.39
INT2—Different types of feedback from teacher or mentor are enabled	5.73	1.59
INT3—Language was clear, subject matter content was comprehensible	6.15	1.35
INT4—Content was well organized and enhances social learning	5.23	1.46
Experiences concerning cognitive load–processing fluency (CL)	5.57	1.14
CL1—I find it easy to memorize fact-laden materials	5.59	1.18
CL2—Learning process was going smooth	5.87	1.22
CL3—I find it easy to think and to learn new content and concepts	5.38	1.74
CL4—Data and information were easy accessible and ready for use	5.44	1.71
Experiences concerning psychomotor difficulty–easiness (PD)	5.41	1.10
PD1—I find it easy to concentrate myself at design activities	5.55	1.50
PD2—Learning by doing was not physical intensive	4.86	1.42
PD3—I find it easy to handle with tools and workshop equipment	6.02	1.44
PD4- I find easy and accurate at measurement and testing	5.23	1.33
Experiences concerning overall satisfaction (S)	5.93	0.87
S1—Overall satisfaction with the IBL teachers	6.24	0.97
S2—Overall satisfaction with the peers	5.86	1.09
S3—Overall satisfaction with the learning content	5.82	1.17
S4—Overall satisfaction with the organization	5.79	1.18

given that the average score was larger than the midpoint score of 4. Overall, students were moderately to high satisfied with their learning experiences in an open learning course in real-classroom settings.

4.2 Correlation analyses

The Pearson correlation coefficients among the scales are presented in Table 6. Perceived experiences of open learning environment were all positively related to satisfaction, processing fluency and psychomotor easiness. It seems that when the interactions of students with their fellow students, instructors, learning environment, or content increased, the level of satisfaction, processing fluency and psychomotor easiness were enhanced. Self-efficacy was also positively related to satisfaction ($r = 0.45$, $p < 0.01$). Students, who had higher self-efficacy in performing course actions tended to be more satisfied with the course, perceived cognitive and psychomotor difficulty are reduced. There was also significant relationship between self-regulated learning and satisfaction ($r = 0.39$, $p < 0.01$), and perceived cognitive and psychomotor difficulty of the course ($r = 0.34$, $p < 0.01$, $r = 0.42$, $p < 0.01$; respectively).

The correlation between the covariates (independent) and the dependent variables (processing fluency, psychomotor ease and satisfaction) was judged to be appropriate. We found a reasonable correlation between the DVs, and between the covariates and the DVs. The correlation between the dependent variables does not differ significantly across the IVs groups.

4.3 (Co) Variance and regression analyses

MANCOVA was first performed to find some single and joint effects of type of group (EL, IBL), and the sex (male, female). F tests showed there was a significant difference between groups for cognitive processing fluency, $F = 6.012$, $df = (1, 265)$, $p = 0.015$

Table 6. Correlations between factors, using Pearson coefficient *r* (*n*=267)

	Learning material	Self-efficacy	Self-regulated learning	Interactions	Processing fluency	Psychomotor easiness	Satisfaction
Learning environment	0.65**	0.67**	0.56**	0.61**	0.37**	0.42**	0.39**
Learning material	–	0.67**	0.54**	0.56**	0.39**	0.35**	0.30**
Self-efficacy		–	0.69**	0.65**	0.36**	0.42**	0.45**
Self-regulated learning			–	0.58**	0.34**	0.42**	0.39**
Interactions				–	0.33**	0.34**	0.36**
Processing fluency					–	0.65**	0.34**
Psychomotor easiness						–	0.37**

** Correlation is significant at the 0.01 level (2-tailed).

(M_{EL} = 5.61, SD = 1.1; M_{IBL} = 5.55, SD = 1.2). Considering sex variable, no significant differences were found on satisfaction, processing fluency and psychomotor ease ($p > 0.05$). However, the *F* tests for both IVs on the preferred scale were also significant, $F = 3.99$, $df = (1,266)$, $p = 0.047$ for satisfaction, while for two other DVs were not. Thus, EL and IBL groups were significantly different in their preferred level of satisfaction. Male students in EL felt more comfortable with learning than other students, Table 7.

MANCOVA was performed also to examine three dependent variables simultaneously, in respect of five independent composite variables, but account for five covariates. The effect of a covariate can serve to reduce error variance, but it can also be used to check that other variables are not confounding the observed outcome. Pillai's Trace test revealed a significant effect of four composite IVs to DVs, Table 8. Effect size (eta squared) was judged to be small to medium. Only a composite variable of Interactions is not significant ($p > 0.05$).

The nature of this effect is not clear from the multivariate test statistic: it tells us nothing about which group is differed from which, or about, e.g., whether the effect of learning environment was on processing fluency, psychomotor easiness, satisfaction, or a combination of all three. Test of between subjects-effects revealed a significant effect of the composite IVs on the DVs. A path model where only significant path coefficients are presented is shown in Fig. 2. The result revealed that the combination of the IVs significantly predicts: (a) student satisfaction ($F(5, 261) = 15.86$, $p < 0.001$), (b) processing fluency ($F(5, 261) = 12.46$, $p < 0.001$), and (c) psychomotor easiness ($F(5, 261) = 16.12$, $p < 0.001$). In total, approximately 67 % of the covariance in student DVs was accounted for by the five predictors. The explained covariance was calculated using R^2 from path model where $R^2 = 0.02$ means a

Table 7. Descriptive statistics of students preferred level of satisfaction considering both, type of learning and sex

Dep. Variable	Group	Sex	Mean	SD	N
Satisfaction	EL	Female	5.80	0.97	20
		Male	6.23	0.76	85
		Total	6.15	0.82	105
	IBL	Female	5.77	0.98	58
		Male	5.79	0.82	104
		Total	5.78	0.88	162
	Total	Female	5.78	0.97	78
		Male	5.99	0.82	189
		Total	5.93	0.87	267

Table 8. Pillai's test of different IVs effects on DVs

Effect	Pillai's Trace	*F*	Hypothesis df	Error df	*p*	η^2*
Learning environment	0.03	2.65	3	259	0.049	0.03
Learning material	0.03	3.17	3	259	0.025	0.04
Self-efficacy	0.04	3.72	3	259	0.012	0.04
Self-regulated learning	0.03	2.72	3	259	0.045	0.03
Interactions	0.01	0.44	3	259	0.722	0.01

η^2*. A measure of effect size (from 0.01 to 0.05—a small effect, of 0.06 to 0.14—medium effect, 0.14 and more—large effect).

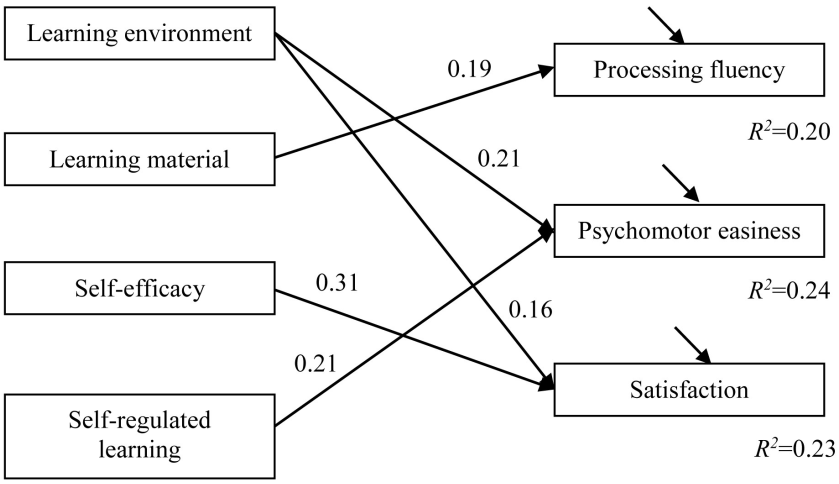

Fig. 2. Perceived course outcomes (right) regressed on students' experiences (left) (n = 267). All reported standardized regression weights are significantly different from zero ($p < 0.01$).

small impact, $R^2 = 0.13$ means a medium effect size, and $R^2 = 0.26$ presents a large effect size [41].

Four composite IVs effect on DVs, surprisingly not significant effect of Interactions composite variable was found. Explained covariance was judged to be moderate to high what depicts a solid path model.

Research revealed that multiple impacts from different composite variables may affect DVs. To see how much the single subject of composite IVs can simultaneously predict DVs, a multiple regression was performed. The result revealed that the combination of the IVs significantly predicts student satisfaction ($F(20, 246) = 7.44$, $p < 0.001$). Approximately 38% of the variance in student satisfaction was accounted for by the twenty predictors. Only significant predictors are shown in Table 4–6. As shown in Table 9, there was no multicollinearity for the predictors with tolerances larger than 0.10 and VIFs smaller than 10.

A clear, comprehensible and accessible content (INT3), user friendly learning environment (LE2) and the multiple forms of learning material (LM4) were surprisingly significant negative predictors in explaining student satisfaction. Enough room for active learning (LE3), attractive content (INT1), which facilitates peer interactions, and the clear instructions and explanations were most positive significant predictors of student satisfaction. The semi-partial correlation (Table 9) informs the uniqueness of a predictor, which is the amount of variance that cannot be explained by other variables entered in the equation. Learner-content interaction (INT3) explained the largest amount of unique variance (20%) in satisfaction compared to other predictors. Self-efficacy and user friendly learning environment followed with 16% of the unique variance in student satisfaction.

Processing fluency might be most positive affected with well equipped and organized classrooms (LE1) and with students' motivation and interest to constructivist approach conducted in learning (SRL4). Surprisingly, large and negative effect was found at subject of user friendly learning environment (LE2) and when own pace of learning was enabled (SRL3), Table 10.

Table 9. Multiple regressions for predictor variables of student satisfaction where only significant predictors are encountered

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics		
Model	***B***	**Std. Error**	***Beta***	***t***	***p***	**Tolerance**	**VIF**	**Semi-partial**
1 (Constant)	3.73	0.30		12.26	0.000			
LE2	–0.19	0.06	–0.33	–3.03	0.003	0.20	4.83	–0.16
LE3	0.15	0.06	0.27	2.64	0.009	0.23	4.21	0.14
LM4	–0.11	0.05	–0.16	–1.85	0.045	0.33	3.00	–0.10
SE1	0.08	0.04	0.14	2.12	0.034	0.55	1.78	0.11
SE3	0.10	0.03	0.21	3.06	0.002	0.49	2.01	0.16
SE4	0.15	0.05	0.25	2.82	0.005	0.31	3.21	0.14
SRL4	0.12	0.04	0.21	2.82	0.005	0.43	2.28	0.14
INT1	0.16	0.06	0.26	2.58	0.010	0.23	4.22	0.13
INT3	–0.28	0.07	–0.43	–3.87	0.000	0.20	4.96	–0.20

Table 10. Multiple regressions for predictor variables of perceived processing fluency where only significant predictors are encountered

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics		
		B	Std. Error	*Beta*	*t*	*p*	Tolerance	VIF	Semi-partial
1	(Constant)	2.52	0.41		6.12	0.000			
	LE1	0.21	0.07	0.25	2.65	0.008	0.29	3.45	0.14
	LE2	–0.28	0.08	–0.36	–3.20	0.002	0.20	4.83	–0.17
	SRL1	0.12	0.06	0.16	1.95	0.048	0.36	2.71	0.10
	SRL3	–0.17	0.05	–0.23	–3.09	0.002	0.46	2.14	–0.16
	SRL4	0.19	0.06	0.25	3.23	0.001	0.43	2.28	0.17
	INT1	0.17	0.08	0.21	2.01	0.045	0.23	4.22	0.11

Learning environment and motivation explained the largest amount of unique variance (17%) in processing fluency compared to other predictors. The comfortable learning environment decreases student motivation to learning. Own pace of learning followed with 16% of the unique variance in perceived processing fluency.

Psychomotor difficulty or easiness is seldom explored in technology and engineering education. Our model predicts food intake (LE4), and attractive and interactive content (INT1) as most positive significant predictors of perceived psychomotor easiness of the course. Again, user friendly learning environment (LE2), and learner-content interactions (INT3) were large and negative predictor of psychomotor easiness, Table 11.

Learning environment and organised refreshments and food available explained the largest amount of unique variance (17%) in psychomotor easiness compared to other predictors. Learner-content interactions seemed to be difficult for middle school students (15%).

For all course outcome variables, a satisfactory amount of variance can be explained by the independent variables. Durbin-Watson test for checking serial dependence revealed critical and significant ($p < 0.01$) values of d (2.01-satisfaction, 1.48-processing fluency, 1.68-psychomotor ease). Since $d > 1.45$ [42], we conclude that there is not enough evidence to infer the presence of positive first-order autocorrelation.

5. Discussion

The purpose of this study was to analyze the effect of important predictor variables on student satisfaction, processing fluency, and psychomotor easiness in a real-classroom setting of robotics-enhanced learning. The investigation of the students' experiences, emotional and psychological outcomes of EL and IBL as constructivist approach yielded some interesting results.

A composite variable of learning environment positively contributes to satisfaction, which confirms the findings of [12, 19, 36] and reduces psychomotor difficulty of the course, already argued by [11]. A subject of user friendly learning environment in real-classroom setting did not contribute positively to satisfaction, processing fluency and psychomotor easiness. This depicts on the bad work habits of students and on a fact that students prefer to work alone interacting with computer only in offline and online settings [18, 35].

The learning material significantly contributes to cognitive processing fluency and reduce intrinsic load also argued by [13] but students did not prefer multiple forms of learning objects. A surplus of learning material may increase extraneous load [13]. Self-efficacy contributes to student satisfaction, also confirmed by [6, 16, 19], and a subject of an amount of needed assistance reduces psychomotor difficulty, argued by [11, 12]. A composite of self-regulated learning did not predict satisfaction,

Table 11. Multiple regressions for predictor variables of perceived psychomotor easiness where only significant predictors are encountered

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics		
		B	Std. Error	*Beta*	*t*	*p*	Tolerance	VIF	Semi-partial
1	(Constant)	2.31	0.38		5.99	0.000			
	LE1	0.14	0.07	0.17	1.89	0.049	0.29	3.45	0.09
	LE2	–0.23	0.08	–0.31	–2.84	0.005	0.20	4.83	–0.14
	LE4	0.21	0.06	0.29	3.38	0.001	0.34	2.93	0.17
	SE2	0.09	0.04	0.12	1.96	0.049	0.59	1.69	0.10
	SE3	0.09	0.04	0.16	2.31	0.021	0.49	2.01	0.12
	SRL1	0.11	0.06	0.16	1.93	0.049	0.36	2.71	0.10
	INT1	0.22	0.08	0.28	2.77	0.006	0.23	4.22	0.14
	INT3	–0.27	0.09	–0.33	–3.00	0.003	0.20	4.96	–0.15

which confirms the findings of [6, 19] but reduce psychomotor difficulty, already confirmed by [11,38], especially when multiple forms of assessment is engaged in learning. Student motivation and interest also reduce germane load, already argued by [13, 33] and contributes to satisfaction, already confirmed by [12, 38]. Surprisingly, a subject of the enabled own learning pace did not contribute to processing fluency. It seems that a time management and no guidance may causes too many interactions what increase germane load and starts to inhibit learning, also argued by [29, 35].

Interactions with clear, comprehensible and not complex learning content in real-classroom setting explained the largest unique variance in student satisfaction and perceived psychomotor easiness (20% and 15%, respectively). Surprisingly, Beta weights are large and negative (–0.43 and –0.33; respectively) even of the fact that comprehensible content enabled a high processing fluency. Along with this, attractive, contemporary and interactive content which suits female and male students evenly positively contributes to satisfaction, decrease germane load and reduce psychomotor difficulty. This finding confirms studies of [16–18, 34, 37]. All aforementioned facts depict on a bad work habits of students [18, 35]. However, when the primary tasks became too easy in content and context or scale, the load scores obtained were high, this time indicating a cognitive disengagement of the learner [20]. Students may be able to apply some of the self-regulation skills properly in their learning, but not in a very refined way. In contrast with on-line and off-line interactions at open learning, learner-content interaction is crucial [19, 43].

About the study, its context, and the classrooms an assumption was made: Ensuring the selection of research groups, where is minimal of EL and IBL, but as many different forms and methods of instruction that promote social learning; the fact is that too little attention to the social aspects of learning can be a serious deficiency at interactions; how students learn depends on their personality traits (temperament, character) and abilities, but also it is different from the content of tasks and situations in which it is located [44].

This study was conducted in light of the following two primary limitations: (1) The summer schools used for this study recruited students from convinced and not random sample. Considering a covariate of pre-acquaintance with robotics subject matter, sample distribution seemed to be normal. (2) The framework for the IBL model, used in this study, is based on 7E model [9], recommended by the CHAIN REACTION project. The framework for EL is based on Kolb's learning cycle [7], recommended by the INFIRO project. Other limitations could consist of the quality of the program, teacher effects, and how the students perform in traditional academic courses.

6. Conclusions

This study indicated that learning environment, learning material, self-efficacy and self-regulated learning were significant composite predictors of robotics-enhanced learning's cognitive, emotional and behavioural outcomes. Composite variable of interactions did not predict significantly course outcomes. Some course disengagements were indicated, what was provoked by bad work habits and by a lack of design thinking of students. Experiential and inquiry-based learning are relatively new for students, but enabled own pace and minimal guidance during instruction caused high cognitive (germane) and psychomotor load even of the fact that learning material was well organized and clear structured. Students felt comfortable with online and offline interactions with content (content-centred learning) rather than peer-to-peer or teacher-student interaction. The learning tools helped the learner to transform intuition into understanding and to consolidate certain experiences into pervasive rules. Thus, an inclusion of additional media tools and technology (e.g., computer-aided design, 3D technology, simulations) may stimulates learners' motivation to learn and in turn increase student interaction with course content and increase retention and learning achievements. Additionally, multiple online/offline types of feedback must be enabled for the entire constructivist learning cycle. The constructivist learning combined with virtual reality and social apprenticeship for experimentation will gather momentum and demand in-depth experimentation in coming years.

The practical implications of this study are that all scientist, teachers and course designers should pay attention to the robotics-enhanced learning design and organisation given that teachers guidance, structured material, experimental and collaborative work with combination of different didactic methods and learning styles substantially contribute to student learning outcomes (e.g., cognitive processing fluency, satisfaction, psychomotor easiness).

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